Fungal contamination of elementary schools: a new environmental hazard

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Background: Sensitivity to fungi is a significant cause of allergic diseases, and prolonged indoor exposure to fungi is a growing health concern.

Objective: This study evaluates the health effects of mold-contaminated schools on students and teachers. A discussion of the effectiveness of current methods for evaluating these schools, with a focus on the importance of using total mold spore counts, is also provided.

Methods: Two Connecticut public schools were tested using multiple air quality testing methods, with the standard for a healthy indoor environment being total mold spore counts lower than 1,000 spores/m^3. The health impact of the mold exposure at each school was evaluated using the validated Rhinitis Outcomes Questionnaire.

Results: The testing of the first school found indoor mold counts ranging from 6,000 to 50,000 spores/m^3. Eighty-five of the students and teachers reported significant allergic symptoms to the school nurse. This school is currently being demolished. More than 2 years after the exposure ended, a number of occupants of the school continue to have elevated symptoms compared with before their exposure to the school. The testing of the second school revealed total mold spore counts ranging between 2,000 and 9,000 spores/m^3, qualifying it an unhealthy environment in need of immediate remediation. Students reported significant allergic symptoms from exposure to certain rooms that are currently being remediated.

Conclusions: Because of the negative impact on health that indoor mold exposure has, particularly in atopic patients, schools should be routinely tested for fungal contamination. Total mold spore counts should be performed using volumetric air sampling such as the Allergenco MK-3 (Allergenco, San Antonio, TX) because testing air quality via semiquantitative culture sampling alone does not give a true reflection of the extent of fungal contamination. Finally, the standard for a healthy indoor environment should be defined as having $<$1,000 spores/m^3.

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INTRODUCTION

Over the past decade there has been an increased awareness among clinicians, as well as the general public, that sensitivity to mold is a significant cause of allergic diseases, including allergic asthma, allergic rhinitis, allergic fungal sinusitis, bronchopulmonary mycoses, and hypersensitivity pneumonitis.[1] Additionally, parents have become more aware of increased illness at the start of the school year, particularly in schools with a history of water damage.

There is evidence in the literature to support the parents' observations. Savilahti et al[2] recently published a study that evaluates whether exposure to molds from moisture damage in a school affected the health of the children. He concluded that moisture damage and exposure to molds increased the indoor air problems of schools and adversely affected the respiratory health of the children.[2]

In a subsequent study, Savilahti et al[3] evaluated the occurrence of immunoglobulin (Ig)E sensitization in patients exposed to schools where there was visible water damage, mold contamination, and complaints of respiratory and skin symptoms. The study showed elevated IgE values among the exposed children and occurrences of new allergic disease after the children started at the contaminated school. The study concluded that exposure to spores, toxins, and other metabolites of molds may have complex results with unknown immunogenic effects; this exposure may act as a nonspecific trigger for allergic sensitization, leading to the development of atopy.[3]

Taskinen et al[4] validated the studies by Savilahti et al[2,3] and concluded that there was an association between moisture and mold problems in a school building and the occurrence of respiratory infections and wheezing in school children.

This is a potentially widespread issue. In June of 1996, the General Accounting Office reported that one-third of the public schools in the United States, serving approximately 14 million pupils nationwide, needed extensive repair or replacement of one or more buildings.

Combined, these factors raise a number of timely issues: How to identify buildings that may be making children sick, what methods should be used to test the air quality, and what is a safe level of indoor molds. This report discusses how these issues were decided in assessing two public schools in Connecticut.

MATERIALS AND METHODS

Two public schools in southern Connecticut were tested: McKinley Elementary School in Fairfield and Tashua Elementary School in Trumbull. Various testers—using methods

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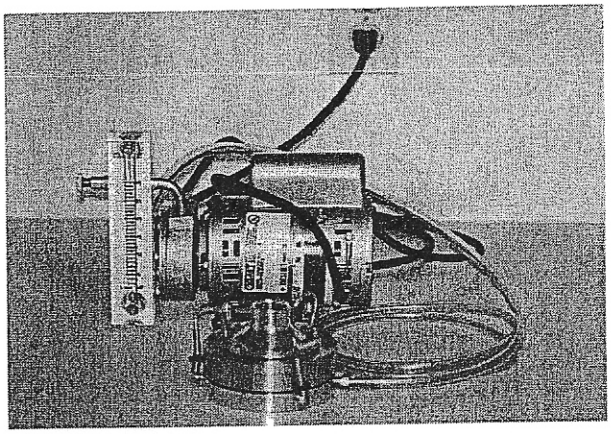

Figure 1. Andersen Air Sampler. OSHA used the Andersen Model 10–709 N-6–1 ACFM single-stage viable impactor sampler with a flow rate of 28.3 L of air per minute onto a standard Petri dish with Sabouraud dextrose agar for 3 minutes.

that are discussed in detail below—performed air quality testing.

The validated Rhinitis Outcomes Questionnaire[5] was used to evaluate the health impact of the indoor mold exposure. The questionnaire quantifies 25 symptoms relating to the students' and teachers' health before becoming ill, at the height of their illness, and after their exposure to the indoor mold has ended. This questionnaire was given to nine teachers/staff and three students who attended or worked in these schools. Additionally, there are summary data on the health of 85 of the students, faculty, and staff at McKinley reported by the school nurse.

Puncture skin testing was performed with the bifurcated small pox needle.[6] Antigens include *Dermatophagoides pteronyssinus*, *Dermatophagoides farinae*, cat, dog, birch, maple and oak, grass mix, ragweed mix, and saline. Molds were tested intradermally[7] up to a concentration of 1:1,000 wt/vol. Results were recorded as millimeters of wheal and erythema.

Methods for Testing of McKinley Elementary School

Occupational Safety and Health Administration (OSHA) performed biologic sampling at McKinley on October 2, 2000. They tested the air quality using an Andersen Air Sampler (Thermo Andersen, Smyrna, GA; Fig 1).

On November 5, 2000, Turner Environmental performed a school-wide environmental testing of McKinley Elementary School.[8] They used a Air-O-Cell Cassette (Zefon International, St. Petersburg, FL; Fig 2) for total spore counts in five rooms and tested the wall cavities in 20 additional rooms with the Zefon cassettes. To test the wall cavities, Turner drilled holes in vertical sections of the wall toward the bottom of the window frame. A wall check adapter was used to reach the air spaces between the brick wall and the plaster finish. Additionally, the carpets in 15 rooms were tested for fungal contamination through the collection of bulk samples of carpet dust, and lastly the school nurse was interviewed.

Methods for Testing Tashua Elementary School

In January 2001, we tested the total mold spore counts in areas where health problems had been reported using the Allergenco MK-3 (Allergenco, San Antonio, TX; Fig 3). In a recent publication by Portnoy et al,[9] the Allergenco MK-3 was standardized against the Burkard Air Sampler (Burkard, Rickmansworth, Hertfordshire, United Kingdom), which is the gold standard for obtaining total pollen and mold spore counts in the outdoor environment. The Allergenco MK-3 was found to be more versatile, portable, and ideal for indoor testing because of its size.

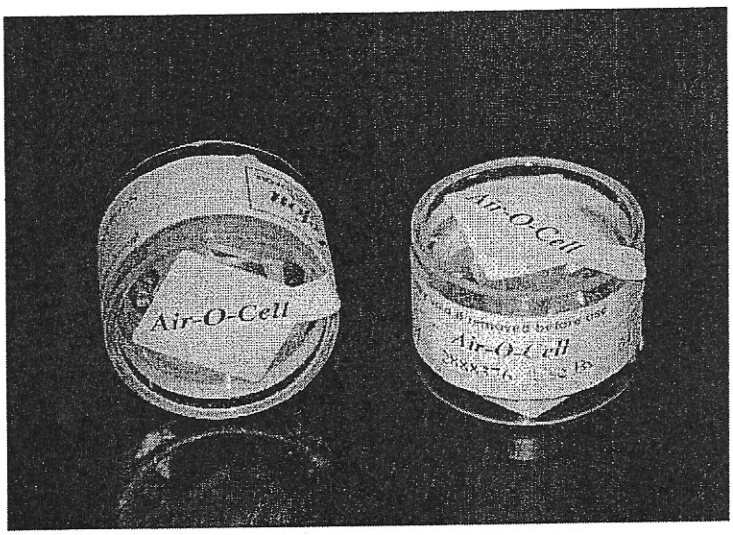

Figure 2. Air-O-Cell Cassettes. Turner Environmental used the Zefon Air-O-Cell. Airborne spores are impacted and adhere to the sampling media contained in the cassette. The pump was calibrated for a flow rate of 15 L per minute. A total sample volume of 150 L was pumped throughout the cassette (600-second run time) past the sampling media. The spores are counted microscopically and reported in spores per cubic meter for each species of fungus identified and also as a total of all species found.

Figure 3. Allergenco Air Sampler. The authors used the Allergenco MK3 programmed for a 10-minute collection. The factory-set flow rate was 15 L per minute and impacted onto a silicone grease-coated slide. Because we were only interested in counting molds and not pollens, we decided not to use a stain. The spores were counted at 400 power counting 1/26 of each strip formed by the sampler on the slide. The resultant number was then converted to counts per cubic meter of air. The slides were read by Dr. Rockwell who completed the American Academy of Allergy, Asthma and Immunology's pollen and mold identification course.

RESULTS

Results for McKinley Elementary School

In a publication by Bush and Portnoy,[10] an unhealthy indoor environment was defined by a mold contamination count >1,000 spores/m³. This standard was used to evaluate the total mold spore count results obtained in this study. For fungal cultures, Etzel[11] states that acceptable levels for airborne fungi are approximately 200 colony forming units (cfu)/m³. This is exclusive of toxinogenic fungi, which are considered unacceptable in indoor air in any amount.

OSHA's air quality testing results showed that the total quantity of colony forming units found in approximately 70% of the indoor sampling exceeded the total quantity of colony forming units in the outdoor sampling. It also revealed the total quantity of colony forming units found in the indoor sample collected from the Faculty Room adjacent to Room 222 was three times greater than the total quantity of colony forming units found in the outdoor ambient air sample (Fig 4).

The fact that several types of molds were detected in the indoor samples that were not detected in the outside sample suggested that there are potential sources of contamination inside the school. Five molds were found indoors that were not found outdoors: *Alternaria*, *Botrytis*, *Curvularia*, *Epicoccum*, and *Stachybotrys*. Molds that were found both outdoors and indoors were *Aspergillus*, *Cladosporium*, and *Penicillium*. The levels of *Aspergillus* and *Penicillium* were higher in some of the indoor rooms compared with outdoors. *Fusarium* was found outdoors but not indoors.

Turner Environmental tested the total mold spore count for McKinley Elementary School. The count in room 107 was extremely high: 53,000 spores/m³. This is high for any indoor environment and was also much higher than other tested rooms in the school (Fig 5). Further testing also revealed severe contamination of the wall cavities and rugs (Table 1).

The results of Turner Environmental's interview of the school nurse revealed that at least 85 of the students, teachers, and staff of McKinley Elementary School reported some type of allergic symptom. The school nurse reported receiving complaints from occupants since the beginning of the school year of symptoms associated with poor indoor air quality from various areas of the building. These symptoms included fatigue, dizziness, postnasal drip, sinus headache/pressure, nasal blockage, skin rashes, earache, eye itching, eye burning,

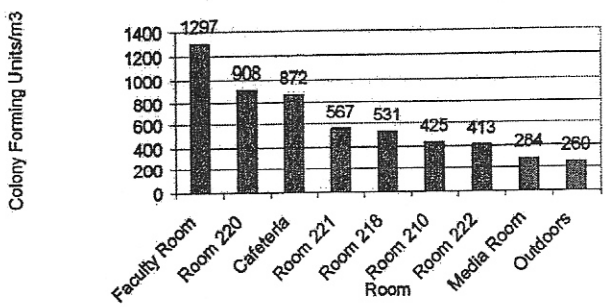

Figure 4. Results of OSHA testing indoor air quality at McKinley Elementary School.

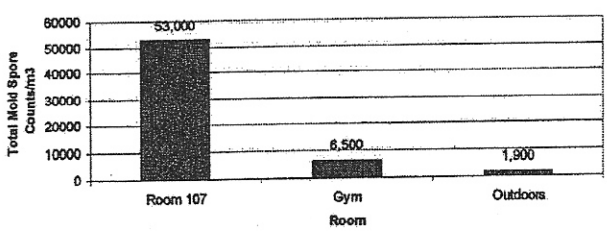

Figure 5. Results of Turner Environmental's testing indoor air quality at McKinley Elementary School.

Table 1. Turner Environmental's Testing of McKinley Elementary School Revealed Severe Mold Contamination of the Wall Cavities and Rugs

Carpet samplings	Colony forming units/Gm
Room 117	108,500,000
Room 118	20,120,000
Room 221	1,970,000
Wall cavity samplings	**Mold spores/m³**
Room 107	156,666
Room 117	106,667
Room 121	120,000

sore throat, wheezing, sneezing, chest tightness, and green/yellow nasal mucus. The nurse had also forwarded reports of moldy musty odors.

Nine of the teachers and staff were evaluated from this school. A Special Education teacher, 48 years old, with a history of mild to moderate asthma and allergic rhinitis had been teaching at McKinley Elementary School since 1991. Her initial symptoms included burning eyes, chronic cough, headaches, fatigue, and irritability. She declined to be skin tested. These symptoms progressed to debilitating fatigue, severe vertigo, and ocular migraines. As the school year progressed her symptoms and overall health worsened. She was forced to leave teaching in November 1998 on medical leave and is presently on Social Security disability. She has been away from the school now for over 4 years and has still not regained her health (Table 2).

The aide to this teacher, working in the same classroom, is a 34-year-old female who presented with sinus congestion, pruritus of eyes and nose, sneezing, rhinorrhea and nasal congestion, cough, wheezing, and extreme fatigue. Positive skin tests were found to tree and grass pollen, mites, cat, *Alternaria*, *Aspergillus*, *Penicillium*, and *Cladosporium* (Table 2).

A second teacher at McKinley Elementary School, a 31-year-old female with a history of allergic rhinitis, asthma, and sinusitis became extremely ill after working for the first 2 months of the 2000–2001 school year. She was skin test positive to dust mites (*D. farinae* and *D. pteronyssinus*), cat, dog, *Alternaria*, *Candida*, *Aspergillus*, *Penicillium*, *Cladosporium*, *Geotrichum*, and *Fusarium*. While teaching at McKinley she suffered from moderate to severe allergic reactions. Her symptoms included postnasal drip, cough, eye symptoms, wheezing, fatigue, sore throat, sinus pain, urticaria, and facial rashes. She also experienced severe asthma attacks that required trips to the emergency room. She was out of work 2 weeks in October 2000. When she returned, McKinley had been closed and she was moved to a different school. She experienced a severe facial rash when she was exposed to her supplies from McKinley (Table 2).

In September 2000, a 38-year-old custodial employee was involved in the removal of the mold-infested carpets and assisted in the initial cleanup. He developed a severe cough and was evaluated by a pulmonologist for asthma and reactive airway disease. He was evaluated in August 2001 for chronic sinusitis and allergic rhinitis and was skin test positive to *Alternaria*, *Candida*, and *Aspergillus*. His symptoms included shortness of breath, wheezing, visual problems, hemoptysis, and the inability to concentrate. He was forced to stop working July 2001 because of failing health and began seeing a psychiatrist in October 2001 for depression. He is currently unable to work and is on Social Security disability. He reports that he has seen a little improvement since leaving the school (Table 2).

The third teacher is a 53-year-old female who initially presented with complaints of nasal congestion and recurrent sinusitis. Initial testing demonstrated positive skin tests to: mites, dog, and multiple molds, including *Penicillium*, *Mucor*, *Rhizopus*, *Saccharomyces*, *Chaetomium*, *Epicoccum*, *Nigrospora*, *Botrytis*, *Curvularia*, *Spondylocladium*, *Cephalosporium*, *Sporobolomyces*, *Aureobasidium*, and *Ulocladium* (Table 2).

The fourth teacher is a 31-year-old female who presented in October 2000 with a 3-year history of nasal congestion, rhinorrhea, and headaches. Initial skin testing revealed positive skin testing to *Alternaria*, *Aspergillus*, and *Penicillium* with a systemic reaction after testing requiring treatment and prednisone (Table 2).

A staff member at McKinley, a 52-year-old female, presented with sinus and ear pressure, itchy eyes, and a very low level of energy since beginning work at McKinley School. Positive skin tests included cat, dog, *Alternaria*, *Penicillium*, and *Cladosporium* (Table 2).

The fifth teacher is a 59-year-old female who initially presented with a history of chronic laryngitis with vocal cord polyps, rhinorrhea, nasal congestion, and headaches and frequent sinus infections. Positive skin tests included mites, dog, tree pollen, weed pollen, *Aspergillus*, *Penicillium*, and *Fusarium* (Table 2).

Table 2. The Rhinitis Outcomes Questionnaire Quantifies 25 Symptoms Relating to the Students' and Teachers' Health before Becoming Ill, at the Height of their Illness, and after their Exposure to the Indoor Mold Has Ended

Patient	Before illness	Height of symptoms	Currently
McKinley teacher #1	40	85	63
Aide to teacher #1	35	94	57
McKinley teacher #2	19	119	89
Custodial employee	5	74	63
McKinley teacher #3	0	70	4
McKinley teacher #4	5	62	3
McKinley staff member	33	76	29
McKinley teacher #5	27	51	28
McKinley teacher #6	0	82	25
Tashua student #1	3	100	8
Tashua student #2	5	74	10
Tashua student #3	0	66	0

This questionnaire was given to nine teachers/staff and three students who attended or worked in these schools. The scores can range from 0 to 125, and higher scores mean greater symptoms.

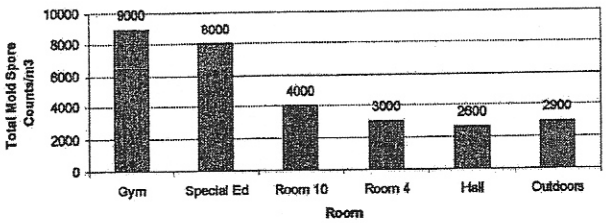

Figure 6. Results of the author's testing air quality at Tashua Elementary School using the Allergenco.

The sixth teacher is a 52-year-old female who presented with chronic sinusitis, headaches, pruritus of eyes and nose, sneezing, rhinorrhea, and congestion. Skin testing revealed a positive reaction to tree pollen, *Aspergillus*, *Penicillium*, *Cladosporium*, *Fusarium*, *Geotrichum*, and *Epicoccum*. An IgG level to *Stachybotrys* was 41.6 mg/L (reference range <20.4; Table 2).

Results for Tashua Elementary School

Tashua Elementary School is another example of an unhealthy indoor environment. Testing of various rooms showed total mold spore counts results ranging from 2,600 to 9,000 spores/m^3. The most affected rooms were the Special Education room and gymnasium (Fig 6).

A 6-year-old boy was originally seen in our office with allergic rhinitis in 1999. He was evaluated and found to be skin test positive to mites and milk and skin test negative to molds. After developing significant allergic problems at school, he was retested in November 2000 and found to be sensitive to *Alternaria*, *Candida*, *Aspergillus*, *Penicillium*, and *Cladosporium*. His symptoms included eye swelling, itching and tearing, accompanied by forgetfulness and moodiness. These symptoms became more severe when he attended school, to the point that he was advised to cease attending that school. Presently he continues to be homebound, and his symptoms have abated with the use of avoidance, antihistamines, and immunotherapy (Table 2).

A 9-year-old girl presented to our office with rhinorrhea and postnasal drip. Her original skin test showed sensitivity to mite and cat only. As she continued to attend school, her symptoms worsened with the development of hives, eczema, stomach pains, epistaxis, dizziness, fatigue, and persistent sore throat. On re-testing, she was found to be sensitive to *Alternaria*, *Candida*, *Aspergillus*, *Penicillium*, and *Cladosporium*. Repeated exposures to the school environment exacerbated her symptoms. She was homebound and experienced far fewer symptoms (Table 2).

An 8-year-old girl presented with severe eczema that seemed to get worse on exposure to the gymnasium, even if the activity there involved instruction rather than exercise. Her skin testing was positive to mites, cat, dog, *Candida*, *Penicillium*, *Cladosporium*, and *Fusarium*. Repeated exposure to the school environment caused exacerbation of the eczema, causing her to be homebound. Although her eczema persists while she is homebound, it is much milder (Table 2).

DISCUSSION

Mold exposure clearly has a negative impact on health, particularly in atopic patients. The mold exposure at McKinley Elementary School caused more than 85 of the students, teachers, and staff to suffer from various symptoms ranging from headaches, postnasal drip, wheezing, skin rashes, and recurrent sinus infections. Several teachers continue to experience health issues even though their exposure ended more than 2 years ago.

Most of the public schools in Connecticut were built in the 1960s and 1970s. Many were built on wetlands, including McKinley, with flat roofs that tended to leak. Over the years, carpets have been installed to cut down on noise and to cover floors with asbestos tiles. It is not surprising that McKinley Elementary School became contaminated with mold. What has been surprising to the town is that the contamination is so extensive that the school must be razed and rebuilt at a cost of US$21 million.

OSHA tested air quality and found that there was a mold problem that needed remediation. OSHA did not define the extent of the problem and did not instruct the board of education on how to remediate the school, so the Board of Education in Fairfield immediately began remediation while the school was in session. The parents and teachers became outraged that the remediation was taking place during school hours, exposing their children to even higher levels of mold. With the help of the media, the parents were able to get the school closed and the children moved to different schools. The Board of Education was also forced to perform further evaluations of the school.

Turner Environmental was hired by the Board of Education and checked total mold spore counts in addition to the air quality tests performed by OSHA. They found one room with an indoor count of 53,000 mold spores/m^3. As 1,000 mold spores/m^3 is considered high, this count meant a severe mold contamination. Further testing by Turner Environmental revealed severe contamination of many wall cavities and rugs. With this information, the Fairfield School Building Committee and First Selectman came to the conclusion that the school was beyond remediation and needed to be replaced.

The authors became aware of an air quality problem at Tashua Elementary School in Trumbull, CT when one of our patients experienced systemic reactions while at school that required several trips to the emergency room for treatment. Using the Allergenco MK-3, we discovered an extensive fungal contamination in both the special education room and the gymnasium, the sites of the patient's reactions. The counts in the rooms were 5,000 spores/m^3 and 7,000 spores/m^3, respectively. These levels signify a problem that can be remediated. The school removed the walls, insulation, and carpeting from the special education room and installed an air purifier. When we retested the room the result was an acceptable 1,000 spores/m^3. The gym has yet to be remediated so the student does not go there.

Not all schools are mold contaminated and Madison Middle School in Trumbull, CT is one example. We evaluated this school at the request of a patient's mother whose son was going to enroll there after being homebound with chronic sinusitis for 2 years and who is highly sensitive to molds. We tested the school using total mold spore counts and found the school to be a healthy environment. The child is currently attending Madison with no adverse affects on his health.

CONCLUSION

Based on our experience, we believe that testing first for total mold spore counts allows for the best initial evaluation of a potentially mold-contaminated environment. If a problem is found, the next step should be an evaluation of the air quality using the Andersen Air Sampler. This will allow for more specific mold identification, especially for identifying *Aspergillus*, *Penicillium*, *Stachybotrys*, and other relevant molds. Additional testing, if necessary, would include wall cavity testing and carpet testing. It is also important to use 1,000 spores/m^3 as the standard for a healthy environment.

Schools, especially those with carpeting, should be routinely tested for fungal contamination. This allows for problems to be identified in their early stages, before severe health problems arise and when remediation is less costly. Testing should be performed using volumetric air sampling because semiquantitative culture sampling alone does not give a true reflection of the extent of fungal contamination. Volumetric air sampling using an Allergenco MK-3 Air Sampler is an easy and inexpensive way to initially evaluate a building for mold contamination and prevent the irreversible health problems that arise from indoor exposure to mold.

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